

## ARSENIC AND COMPOUNDS

Inorganic Arsenic was identified as a toxic air contaminant under California's air toxics program (AB 1807) in 1990.

Arsenic compounds (inorganic including arsine) are federal hazardous air pollutants and were identified as toxic air contaminants in April 1993 under AB 2728.

CAS Registry Number: 7440-38-2

As

Molecular Formula: As

Arsenic is a silver-grey brittle, crystalline (hexagonal, rhombic), metallic-looking substance which exists in three allotropic forms (yellow, black, and grey). It is odorless and nearly tasteless. Arsenic is soluble in nitric acid, cold hydrochloric, and sulfuric acids. It is insoluble in water and nonoxidizing acids. Arsenic compounds are generally non-volatile except for gaseous arsines and arsenic trioxide. Arsenic trioxide is a solid at room temperature but sublimates at 193 °C (Merck, 1989; ARB, 1990g). Table I lists some physical and chemical properties of arsenic compounds.

### Physical Properties of Arsenic

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Synonyms: arsenic black; arsenicals; colloidal arsenic; grey arsenic; metallic arsenic; arsenic-75

Molecular Weight:	74.92
Valence:	3,5
Boiling Point:	Sublimes at 612 °C
Melting Point:	817.0 °C at 28 atm
Vapor Pressure:	1.0 mm Hg at 372 °C
Density/Specific Gravity:	5.727 at 14 °C

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(HSDB, 1995; Merck, 1989; Sax, 1989; U.S. EPA, 1994a)

## SOURCES AND EMISSIONS

### A. Sources

Combustion and high-temperature processes are the largest sources of inorganic arsenic emissions to the atmosphere (ARB, 1990g). Arsenic is used in metallurgy for hardening copper, lead, and alloys. It is also used in the manufacturing of certain types of glass (Merck, 1989).

Most commercial arsenic products are manufactured using arsenic trioxide as the raw material which serves as the basis for approximately 50 other arsenic compounds produced in the United States (ARB, 1990g).

The primary stationary sources that have reported inorganic arsenic emissions in California are electrical services and metal mining (ARB, 1997b). Other sources of inorganic arsenic emissions may include, windblown dust from dry lakebeds and playas of eastern California, glass manufacturing, agricultural burning, waste incineration, secondary lead smelting, resource recovery operations, and tobacco smoking. Arsine gas, arsenic trioxide, elemental arsenic, gallium arsenide, and arsenic trichloride are used by semiconductor manufacturers in California manufacturing of printed circuits and microchips (ARB, 1990).

Arsenic acid is registered by the Department of Pesticide Regulation (DPR) as an insecticide, and is used as a wood preservative to prevent termite damage to wood products. Arsenic pentoxide is registered as a fungicide and insecticide, and is used as a wood preservative to prevent fungal and insect damage to wood products. Arsenic trioxide is registered as an insecticide, and is used in ant stakes to control ants in and around buildings, household dwellings, gardens, and around ornamental trees and bushes (DPR, 1996).

The licensing and regulation of pesticides for sale and use in California are the responsibility of DPR. Information presented in this fact sheet regarding the permitted pesticidal uses of arsenic acid, arsenic pentoxide, and arsenic trioxide has been collected from pesticide labels registered for use in California and from DPR's pesticide databases. This information reflects pesticide use and permitted uses in California as of October 15, 1996. For further information regarding the pesticidal uses of this compound, please contact the Pesticide Registration Branch of DPR (DPR, 1996).

## B. Emissions

The total emissions of arsenic and arsenic compounds from stationary sources in California is estimated to be at least 13,000 pounds per year, based on data reported under the Air Toxics "Hot Spots" Program (AB 2588) (ARB, 1997b). In January 1993, the Air Resources Board (ARB) adopted an air toxics control measure for non-ferrous metal melting operations. This control measure is expected to reduce emissions of arsenic, cadmium, and nickel (ARB, 1992f).

## C. Natural Occurrence

In nature, arsenic is found to a small extent as the element, mostly as an arsenide of true metals (Merck, 1989). It is found especially in sulfide ores. Arsenic composes  $5 \times 10^{-4}$  percent of the earth's crust. Minerals which include arsenic are: arsenopyrite, orpiment, realgar, claudetite, cobaltite, and enargite. Inorganic arsenic is released into the air by volcanoes and the weathering of arsenic-containing minerals and ores (U.S. EPA, 1994a)

Due to natural geochemical enrichment in California, arsenic is found in both above ground and below ground drinking water, and total exposure to arsenic from drinking water is usually far higher than total exposure from inhalation from the ambient air (ARB, 1990g).

## **AMBIENT CONCENTRATIONS**

Arsenic and its species are routinely monitored by the statewide ARB air toxics network. The network's mean concentration of arsenic from January 1996 through December 1996 is estimated to be 1.5 nanograms per cubic meter (ng/m<sup>3</sup>) (ARB, 1997c).

## **INDOOR SOURCES AND CONCENTRATIONS**

Few indoor sources of arsenic other than tobacco smoke have been identified. The arsenic content of mainstream cigarette smoke ranges from 40 to 120 nanograms of arsenic per cigarette (U.S. DHHS, 1989). Acute toxic effects due to high inorganic arsenic exposures have been reported in buildings constructed on top of arsenic waste sites and in homes where wood treated with arsenic wood preservatives has been burned in the fireplaces or woodstoves. Less significant sources of arsenic in offices and residences of nonsmokers include indoor combustion of non-preserved wood or other fuels, and infiltration of street dust (ARB, 1990g).

In a field study conducted in southern California, investigators collected particles (PM<sub>10</sub>) inside 178 homes and analyzed the particle samples for selected elements, including arsenic. Two consecutive 12-hour samples were collected inside and immediately outside each home. Arsenic was present in measurable amounts in less than 10 percent of the samples (Clayton et al., 1993).

## **ATMOSPHERIC PERSISTENCE**

Arsenic exists as both organic and inorganic compounds, and in both the gas and particulate matter phases. The majority of atmospheric arsenic is highly respirable inorganic arsenic particulate matter smaller than 2.5 micrometers. Heating of most arsenic-containing compounds in the presence of air results in the oxidation of the arsenic bound in the mineral. The product of this oxidation is primarily arsenic trioxide. Conditions in the ambient atmosphere favor oxidation, so inorganic arsenic (V) compounds are generally expected to predominate in unimpacted ambient air (ARB, 1990g).

The atmospheric lifetime of inorganic, particulate-phase arsenic is typically 5 to 15 days due to wet and dry deposition (Balkanski et al., 1993).

## **AB 2588 RISK ASSESSMENT INFORMATION**

The Office of Environmental Health Hazard Assessment reviews risk assessments submitted under the Air Toxics "Hot Spots" Program. Of the risk assessments reviewed as of April 1996,

arsenic and compounds were the major contributors to the overall cancer risk in 38 of the approximately 550 risk assessments reporting a total cancer risk equal to or greater than 1 in 1 million and contributed to the total cancer risk in 171 of these risk assessments. Arsenic and compounds also were the major contributors to the overall cancer risk in 14 of the approximately 130 risk assessments reporting a total cancer risk equal to or greater than 10 in 1 million, and contributed to the total cancer risk in 65 of these risk assessments (OEHHA, 1996a).

For non-cancer health effects, arsenic and arsenic compounds contributed to the total hazard index in 16 of the approximately 89 risk assessments reporting a total chronic hazard index greater than 1. Arsenic and arsenic compounds also contributed to the total hazard index in 5 of the approximately 107 risk assessments reporting a total acute hazard index greater than 1. Arsenic, by itself, contributed to the total hazard index in 1 of the approximately 107 risk assessments reporting a total acute hazard index greater than 1 (OEHHA, 1996b).

## HEALTH EFFECTS

Arsenic may be absorbed by ingestion, inhalation, and permeation of skin or mucous membranes.

**Non-Cancer:** By ingestion, as little as 20 milligrams of arsenic may be life-threatening to man. Acute airborne exposure to high concentrations of arsenic (III) trioxide in occupational settings causes irritation of the eyes, nasal mucosa, and bronchi. Non-carcinogenic effects associated with chronic occupational exposure to high concentrations of airborne arsenic include nasal septum ulceration and perforation, respiratory tract irritation, and peripheral neuropathy. The most sensitive noncarcinogenic endpoints are vascular disorders (hemolysis), neurological disturbances, and adverse reproductive effects. Other reported effects from acute inhalation exposure include gastrointestinal effects (nausea, diarrhea, and abdominal pain). Chronic inhalation exposure to inorganic arsenic in humans is associated with irritation of the skin and mucous membranes, while chronic oral exposure has resulted in gastrointestinal effects, anemia, peripheral neuropathy, skin lesions, and liver or kidney damage (U.S. EPA, 1994a).

An acute non-cancer reference exposure level (REL) of  $1.3 \times 10^2 \mu\text{g}/\text{m}^3$  is listed for arsenic in the California Air Pollution Control Officers Association Air Toxics "Hot Spots" Program, Revised 1992 Risk Assessment Guidelines. The toxicological endpoint considered was blood. For arsenic, CAPCOA lists a chronic non-cancer REL of  $0.5 \mu\text{g}/\text{m}^3$  with toxicological endpoints of the respiratory and central and peripheral nervous systems, and skin (CAPCOA, 1993). The United States Environmental Protection Agency (U.S. EPA) has not established a Reference Concentration (RfC) for inorganic arsenic. The RfC for arsenic is  $5 \times 10^{-2} \mu\text{g}/\text{m}^3$  based on increased hemolysis, abnormal red blood cell morphology, and increased spleen weight in rats, mice, and hamsters. The U.S. EPA estimates that inhalation of this concentration or less over a lifetime would not likely result in the occurrence of chronic non-cancer effects. The oral Reference Dose (RfD) for inorganic arsenic is 0.3 micrograms per kilogram per day based on hyperpigmentation, keratosis, and possible vascular complications in humans. The U.S. EPA has

not established an RfD for arsine (U.S. EPA, 1994a).

Adverse pregnancy outcomes have been observed among copper smelter employees and nearby residents: these included spontaneous abortion and low birthweight. Malformation rates were found to be increased in employees. Interpretation of the data is complicated by the presence of toxicants other than arsenic from the smelter processes. Inorganic arsenic administered by injection or gavage during embryogenesis can cause malformation, embryoletality and growth retardation in mice, hamsters and rats. Trends toward increasing numbers of skeletal malformations with increasing dose were observed in the offspring of mice exposed to arsenic trioxide by inhalation (ARB, 1990g). The State of California under Proposition 65 has determined that arsenic (inorganic oxides) is a developmental toxicant (CCR, 1997).

Cancer: Evidence for carcinogenicity in humans due to inhaled arsenic is strong. Studies of workers in smelters and in the pesticide manufacturing industry have found strong, consistent associations between respiratory cancer and arsenic exposure. The effect on respiratory cancer rates of combining smoking and arsenic exposure appears to be greater than additive and at low doses may be as high as multiplicative (ARB, 1990g).

The U.S. EPA has not classified arsine as to its carcinogenicity. The U.S. EPA has classified inorganic arsenic as Group A, human carcinogen, based on sufficient epidemiological evidence with an inhalation potency value of  $4.3 \times 10^{-3}$  (microgram per cubic meter)<sup>-1</sup>. The U.S. EPA estimates that if an individual were to breathe air containing  $2 \times 10^{-4} \mu\text{g}/\text{m}^3$  over a lifetime, that person would theoretically have no more than a 1 in 1 million increased chance of developing cancer (U.S. EPA, 1994a). The International Agency for Research on Cancer has classified inorganic arsenic and arsenic compounds as Group 1: Human carcinogen based on sufficient evidence in humans (IARC, 1987a).

The State of California has determined under Proposition 65 and AB 1807, that inorganic arsenic compounds are carcinogens (CCR, 1996; ARB, 1990g). The inhalation potency factor that has been used as a basis for regulatory action in California is  $3.3 \times 10^{-3}$  (microgram per cubic meter)<sup>-1</sup> (OEHHA, 1994). In other words, the potential excess cancer risk for a person exposed over a lifetime to  $1 \text{ ng}/\text{m}^3$  of inorganic arsenic is at most three in one million (OEHHA, 1994).

**TABLE I - PHYSICAL PROPERTIES OF ARSENIC COMPOUNDS**

<b>Molecular Formula &amp; Substance Name</b>	<b>CAS Registry Number</b>	<b>Synonyms</b>	<b>Molecular Weight</b>	<b>Boiling Point °C</b>	<b>Melting Point °C</b>	<b>Density</b>	<b>Water Solubility</b>
As <sub>2</sub> O <sub>5</sub> arsenic pentoxide	1303-28-2	arsenic oxide; arsenic anhydride; arsenic acid	229.84	---	800	4.32	1.5 Kg (16 °C)
H <sub>3</sub> AsO <sub>4</sub> •1/2H <sub>2</sub> O arsenic acid (hemihydrate)	7774-41-6	orthoarsenic acid, hemihydrate	150.96	160	35.5	2.0 - 2.5	170g (20 °C)
Ca <sub>3</sub> (AsO <sub>4</sub> ) <sub>2</sub> calcium arsenate	7778-44-1	tricalcium arsenate; pencal; calcium orthoarsenate	398	---	---	---	0.13g (25 °C)
PbHAsO <sub>4</sub> lead arsenate	7784-40-9	schultenite	347.12	decomposes at 720	---	---	v. sl soluble
As <sub>2</sub> O <sub>3</sub> arsenic trioxide	1327-53-3	crude arsenic; arsenous acid; arsenious oxide	395.68	460	278	---	21g (25 °C)
NaAsO <sub>2</sub> sodium arsenite	7784-46-5	sodium metaarsenite	---	---	---	---	very soluble
As <sub>2</sub> S <sub>3</sub> arsenic sulfide	1303-33-9	arsenious sulphide; arsenic trisulfide	246.04	707	312	3.43	insoluble in water
AsH <sub>3</sub> arsine	7784-42-1	arsenic hydride; hydrogen arsenide	77.95	-55	-116	2.695	200 ml (20 °C)
CH <sub>3</sub> AsO <sub>3</sub> HNa monosodium methylarsonate	2163-80-6	bueno; ansar 170; weed hoe; MSMA	161.96	---	155 - 119	---	570g (25 °C)
(CH <sub>3</sub> ) <sub>2</sub> AsO <sub>2</sub> H cacodylic acid	75-60-5	hydroxydimethyl arsine oxide; dimethylarsinic acid	138.01	---	192	---	830g (22 °C)
C <sub>6</sub> H <sub>4</sub> NH <sub>2</sub> AsO <sub>3</sub> H <sub>2</sub> arsanilic acid	98-50-0	atoxylic acid; p-aminobenzene-arsonic acid	217.06	---	232	---	soluble (hot)

(Sax, 1989; ARB, 1990; Merck, 1989)